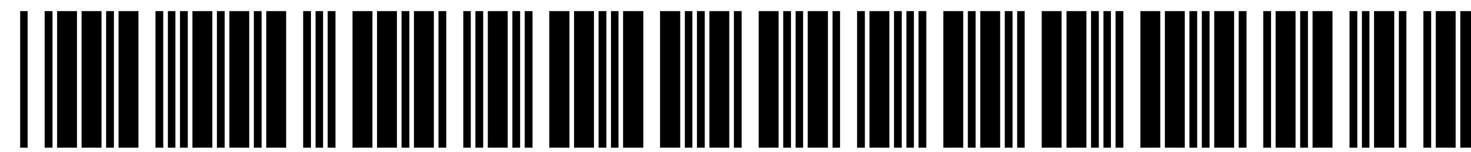

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Hiramatsu et al.

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(54) **METHOD OF MANUFACTURING DISPLAY DEVICE HAVING A MULTILAYERED UNDERCOATING LAYER OF SILICON OXIDE AND SILICON NITRIDE**

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See application file for complete search history.

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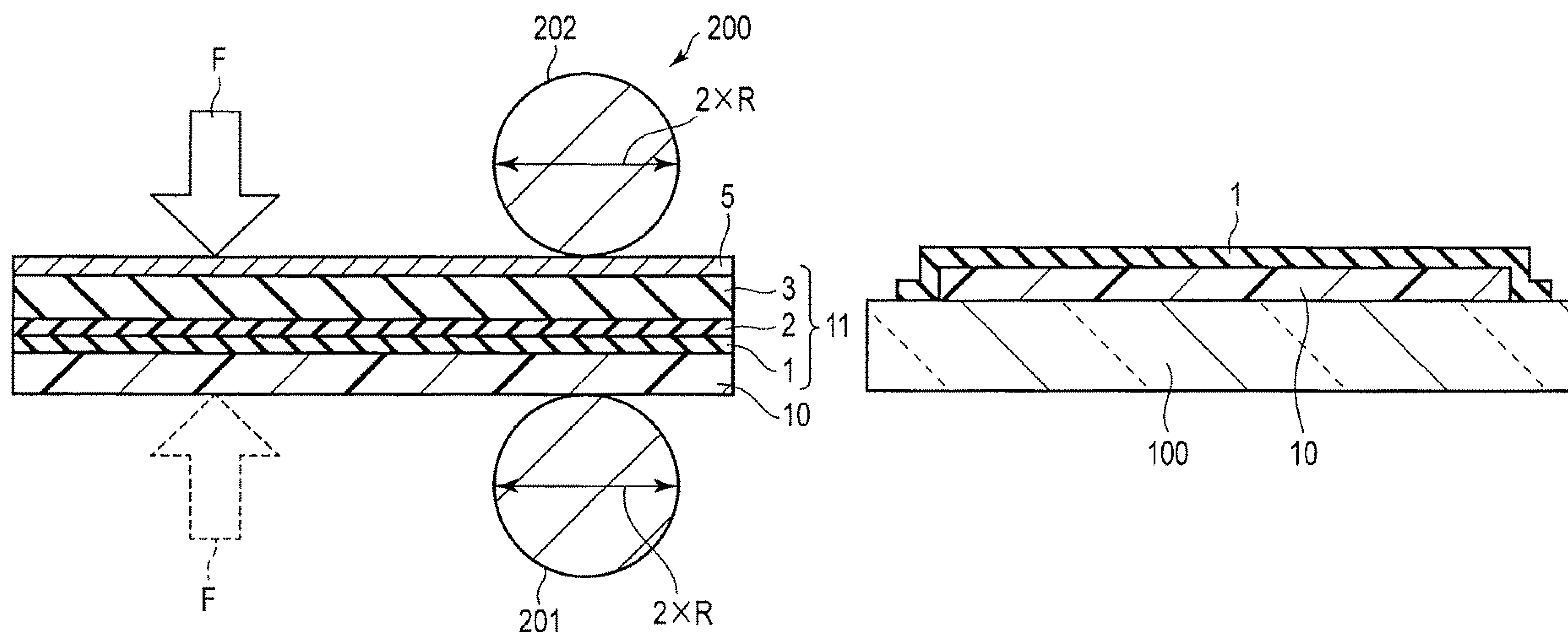
(57) **ABSTRACT**

According to one embodiment, a display device includes an underlying insulation layer formed on a surface of a resin layer, and a thin-film transistor formed above the surface of the resin layer via the underlying insulation layer. The underlying insulation layer includes a three-layer multilayer structure of a first silicon oxide film, a silicon nitride film formed above the first silicon oxide film, and a second silicon oxide film formed above the silicon nitride film.

13 Claims, 4 Drawing Sheets



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H01L 29/786 (2006.01)

(52) **U.S. Cl.**
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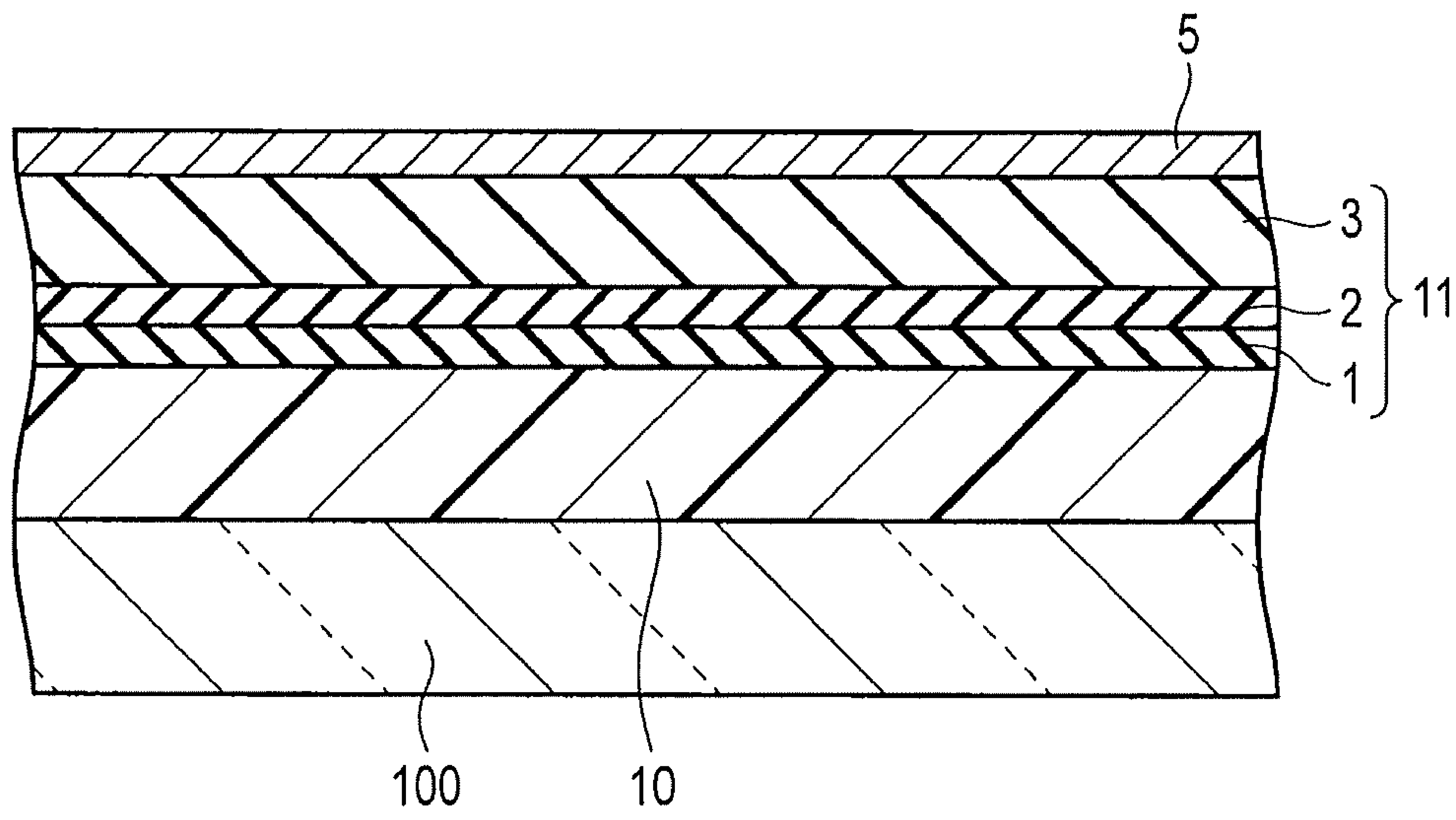
FIG. 1



F I G. 2

	Evaluation objects	Minimum bend R (Downward)	Minimum bend R (Upward)
Example 1	Multilayer member of resin layer/ underlying insulation layer/a-Si layer Thickness of first silicon oxide film: 50 nm	2 [mm]	2 [mm]
Example 2	Multilayer member of resin layer/ underlying insulation layer/a-Si layer Thickness of first silicon oxide film: 10 nm	2 [mm]	2 [mm]
Example 3	Multilayer member of resin layer/ underlying insulation layer/a-Si layer Thickness of first silicon oxide film: 30 nm	2 [mm]	2 [mm]
Example 4	Multilayer member of resin layer/ underlying insulation layer/a-Si layer Thickness of first silicon oxide film: 100 nm	2 [mm]	2 [mm]
Comparative example 1	Resin layer alone	2 [mm]	2 [mm]
Comparative example 2	Multilayer member of resin layer/ second silicon oxide film	2 [mm]	2 [mm]
Comparative example 3	Multilayer member of resin layer/silicon nitride film/second silicon oxide film/a-Si layer	25 [mm]	30 [mm]

FIG. 3

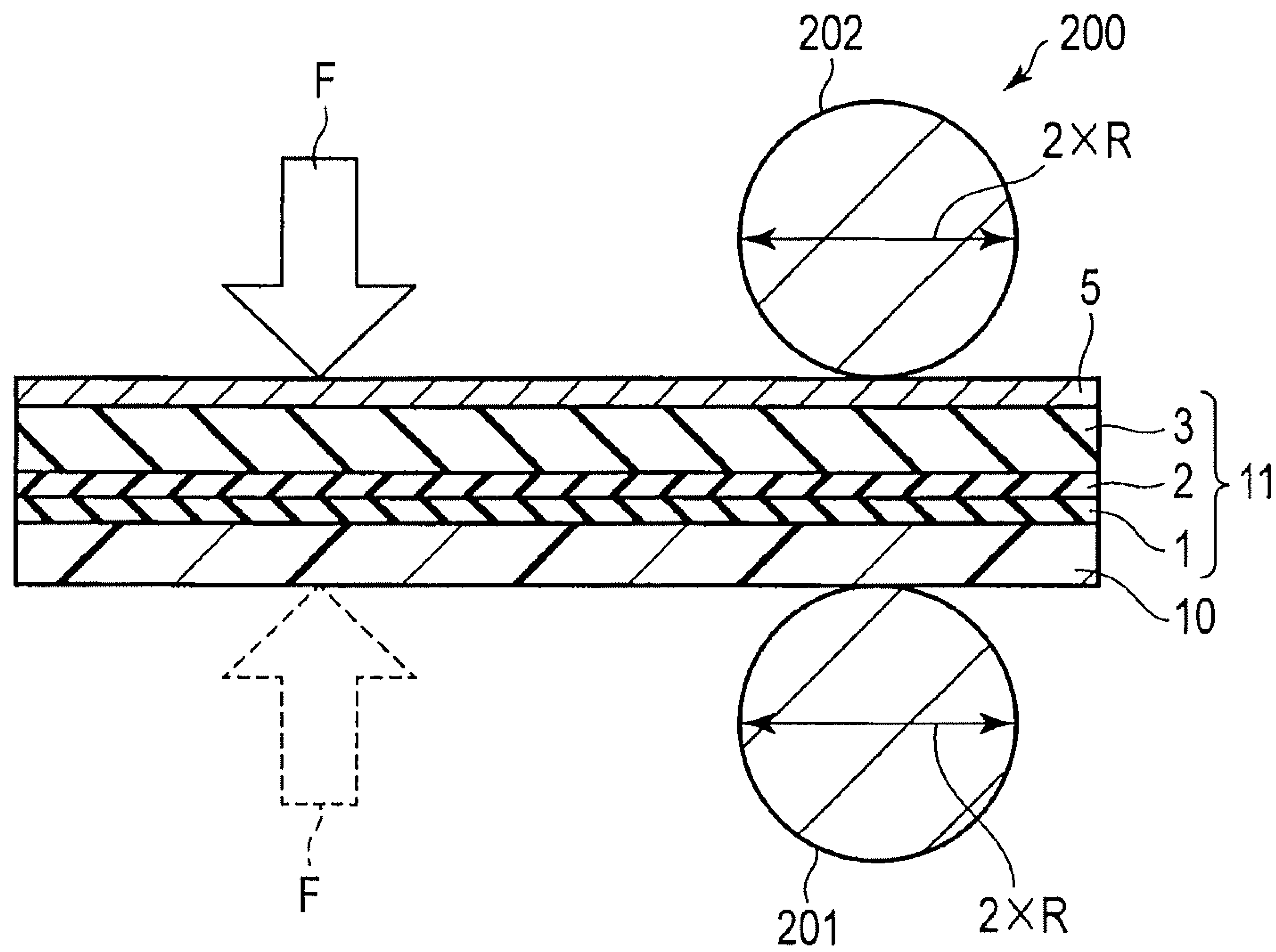


FIG. 4

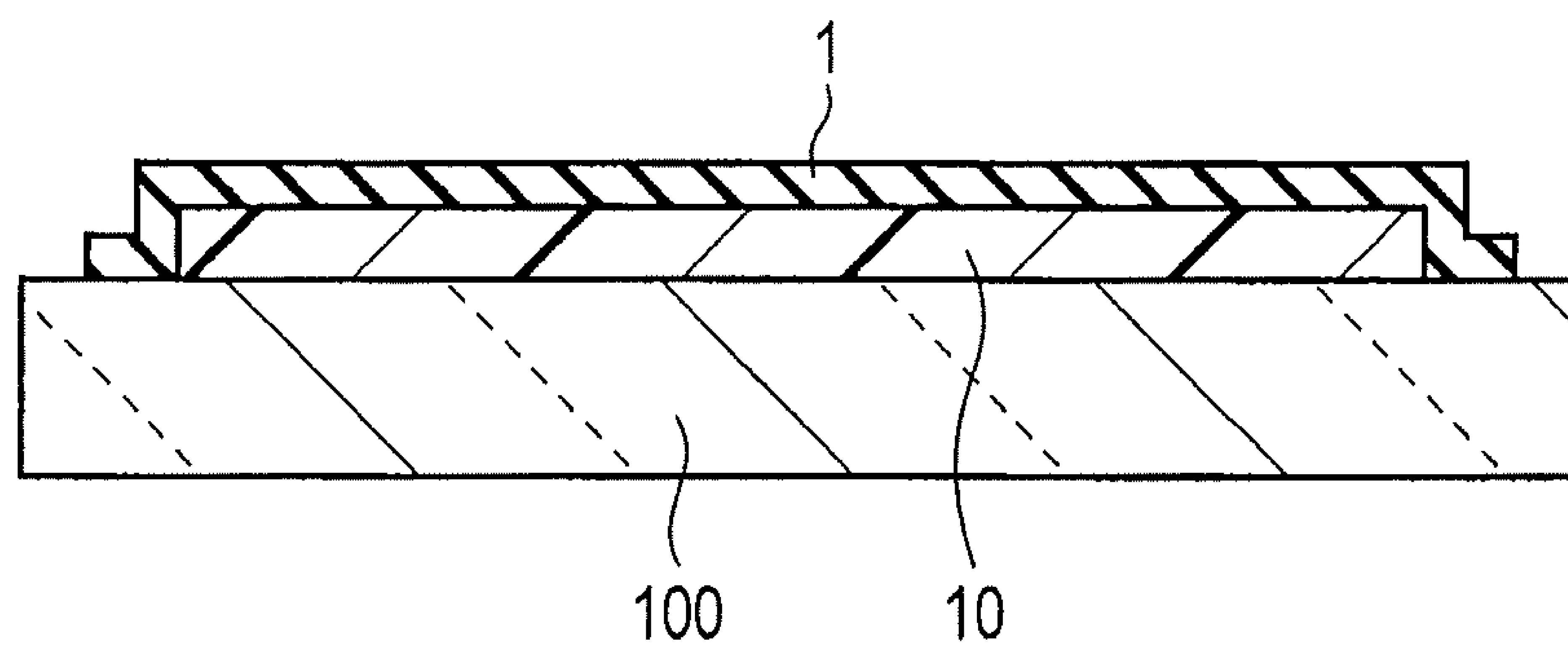


FIG. 5

METHOD OF MANUFACTURING DISPLAY DEVICE HAVING A MULTILAYERED UNDERCOATING LAYER OF SILICON OXIDE AND SILICON NITRIDE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. Ser. No. 14/513,653, filed Oct. 14, 2014, now allowed; which is based upon and claims the benefit of priority from Japanese Patent Application No. 2013-216298, filed Oct. 17, 2013, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a display device.

BACKGROUND

By virtue of such advantageous features as light weight, small thickness and low power consumption, flat-panel display devices, such as an organic electroluminescence (EL) display device and a liquid crystal display device, have been used in various fields of OA (office automation) equipment, information terminals, timepieces, and television receivers. In particular, by virtue of high responsivity, display devices using thin-film transistors (TFTs) are widely used as monitors of mobile terminals, computers, etc., which display a great deal of information.

In recent years, as regards mobile information terminal devices such as mobile phones and PDAs (personal digital assistants), there has been an increasing demand for a display device having a less thickness and a less weight, from the standpoint of design and portability, as well as performance. For example, display devices, which realize thinner structures, have been proposed. As a method of realizing a less thickness and less weight, there is known a technique wherein a resin layer formed of a polyimide with a relatively high heat resistance, or a plastic substrate, is used in place of a glass substrate. When a resin layer is formed of a polyimide, a resin layer using a polyimide is formed on a glass substrate. After TFTs, etc. are formed on the resin layer, the resultant structure is divided into cells, and at last the resin layer is peeled from the glass substrate. Thereby, the resin layer can be formed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view which schematically illustrates a display device of a first embodiment.

FIG. **2** is a cross-sectional view which schematically illustrates a part of the display device in a manufacturing process of the display device, FIG. **2** illustrating a state in which a resin layer, an underlying insulation layer and an a-Si layer are stacked on a glass substrate.

FIG. **3** is a view showing, in a table, evaluation objects and minimum bend R in Examples 1 to 4 of a second embodiment and Comparative Examples 1 to 3.

FIG. **4** is a cross-sectional view illustrating a jig of the second embodiment, FIG. **4** also illustrating a multilayer member of a resin layer, an underlying insulation layer and an a-Si layer.

FIG. **5** is a cross-sectional view which schematically illustrates a part of a display device of a third embodiment, FIG. **5** illustrating a glass substrate, a resin layer and a first silicon oxide film.

DETAILED DESCRIPTION

In general, according to one embodiment, there is provided a display device comprising: an underlying insulation layer formed on a surface of a resin layer; and a thin-film transistor formed above the surface of the resin layer via the underlying insulation layer. The underlying insulation layer includes a three-layer multilayer structure of a first silicon oxide film, a silicon nitride film formed above the first silicon oxide film, and a second silicon oxide film formed above the silicon nitride film.

To begin with, the basic concept of embodiments of the invention is described.

A display device is formed, for example, by forming a TFT (thin-film transistor) above a glass substrate or a resin layer. An undercoating layer is provided between the glass substrate or resin layer and the TFT. The undercoating layer is provided in order to prevent contamination of the TFT (diffusion of impurities from the glass substrate or resin layer into the TFT). In addition, the undercoating layer is an underlying insulation layer and is electrically isolated from the TFT.

For example, in the case of forming the display device by using the glass substrate and forming the TFT by using Si (silicon), the undercoating layer is formed, for example, on the glass substrate, and the TFT is formed above the glass substrate via the undercoating layer. The undercoating layer includes a two-layer multilayer structure, and includes a SiN_X film (silicon nitride film) and a SiO_2 film (silicon oxide film). The SiN_X film is formed on the glass substrate, and the SiO_2 film is formed on the SiN_X film. Since SiN_X and SiO_2 are inorganic materials, for example, the SiN_X film and SiO_2 film are formed by using a plasma CVD (chemical vapor deposition) method.

The advantage and disadvantage of the SiN_X film are described below.

Advantage: Since the SiN_X film has excellent ion blocking properties, contamination of the TFT can be prevented.

Disadvantage: In a case where a Si layer is formed immediately above the SiN_X film, there is a case in which the electrical characteristics of the TFT are adversely affected and the use of the TFT as a switching element becomes difficult. The reason for this is that when the Si layer is made polycrystalline, nitrogen atoms (excess nitrogen) of structural elements of the SiN_X film are supplied into the Si layer. Since the above has the same function as an N-type dopant, the Si layer is undesirably made to have a function of discharging electrons. In other words, nitrogen atoms function as donors in the Si layer, and an electric current tends to easily flow when an electric current is not to be caused to flow. Furthermore, in other words, even in the condition in which the channel region of the Si layer has to be made to have high resistance, a leak current flowing in the channel region increases.

Next, the advantages and disadvantage of the SiO_2 film are described.

Advantage 1: The affinity with the Si layer is excellent.

Advantage 2: The effect at a time of impurity doping is small.

Advantage 3: The supply of nitrogen atoms (excess nitrogen) from the SiN_X film to the Si layer can be prevented.

Disadvantage: The contribution to the prevention of contamination of the TFT is poor.

Next, a description is given of a manufacturing method for forming an undercoating layer and a TFT using p-Si (polysilicon) on a glass substrate.

In this case, the undercoating layer and a-Si (amorphous silicon) layer are, in many cases, formed at the same opportunity. For example, in the same CVD reaction chamber in which the temperature of a glass substrate is about 400° C., three layers, namely a SiN_X film, a SiO_2 film and an a-Si layer, are successively formed in order on the glass substrate by only switching supply gases. The SiN_X film is formed on the glass substrate by plasma decomposition of a mixture gas of SiH_4 gas and NH_3 gas. The SiO_2 film is formed on the SiN_X film by plasma decomposition of a mixture gas of SiH_4 gas and N_2O gas. The a-Si layer is formed on the SiO_2 film by plasma decomposition of SiH_4 gas. Subsequently, an ordinary fabrication process of a TFT using low-temperature p-Si will be performed.

As has been described above, when the TFT is formed above the glass substrate, the undercoating layer is formed of two layers, namely the SiN_X film and SiO_2 film. Thereby, a display device with excellent product reliability can be obtained.

In the meantime, among display devices, a display device including, in place of the glass substrate, a substrate formed of a material with good flexibility has been developed. This aims at obtaining a display device which is excellent in product reliability and is excellent in flexibility (i.e. is hardly crackable). Furthermore, this display device is advantageous, for example, in that the product design is not restricted, unlike a display device including a glass substrate.

In general, there are the following two kinds of fabrication methods of the substrate with excellent flexibility.

(1) A plastic substrate (resin substrate) is used in place of the glass substrate.

(2) A resin layer (e.g. a resin layer using a polyimide) is formed on the glass substrate, and the resin layer is peeled from the glass substrate. Thereby, this resin layer is used in place of the glass substrate.

In addition, also in the case of forming the display device by using the plastic substrate or resin layer, the undercoating layer is formed on the plastic substrate or resin layer in order to prevent contamination of the TFT. The TFT is formed above the plastic substrate or resin layer via the undercoating layer. Besides, in this case, it can be thought that the undercoating layer is formed of two layers, namely a SiN_X film and a SiO_2 film. The SiN_X film is formed on the surface of the resin layer (the surface of the plastic substrate or the surface of the resin layer), and the SiO_2 film is formed on the SiN_X film.

However, when the SiN_X film is formed on the surface of the resin layer as described above, such a problem arises that the resin layer (in particular, a surface of the resin layer) changes in quality. The change in quality, in this context, means that the resin layer is hardened and the flexibility (softness) of the resin layer is lost. If the resin layer changes in quality, the resin layer becomes fragile and a crack (brittle fracture) tends to easily occur. Thus, even if the display device is formed by replacing glass with resin, it is difficult to obtain the display device having excellent flexibility.

The reason for this is that when the SiN_X film is formed, the surface of the resin layer, which is heated up to a high temperature of about 400° C., is exposed to NH_3 gas having a high reducing property. Incidentally, even when the SiN_X film was formed without using NH_3 gas, a change in quality occurred in the resin layer (the surface of the resin layer). For example, even if the SiN_X film is formed by plasma decomposition of a mixture gas of SiH_4 gas and N_2 gas, a change in quality occurs in the resin layer (the surface of the resin layer). In addition, even if the a-Si film is formed by plasma decomposition of SiH_4 gas alone, a change in quality occurs in the resin layer (the surface of the resin layer). From the above, it was understood that a change in quality occurs in the resin layer (the surface of the resin layer) if the resin layer (the surface of the resin layer) is exposed to a reducing atmosphere.

As is understood from the above, in the above-described method of forming the undercoating layer (underlying insulation layer), it is difficult to obtain a display device with excellent flexibility.

In the embodiment of the present invention, a display device with excellent flexibility and product reliability can be obtained, so that the above problem can be solved. Next, the means and method for solving the above problem will be described.

Next, a display device of a first embodiment will be described in detail with reference to the accompanying drawings. In the embodiment, an organic EL display device is described as an example of a sheet-shaped display device.

Incidentally, the disclosure is merely an example, and easily conceivable proper changes within the spirit of the invention are included in the scope of the invention as a matter of course. In addition, in some cases, in order to make the description clearer, the widths, thicknesses, shapes, etc. of the respective parts are schematically illustrated in the drawings, compared to the actual modes. However, the schematic illustration is merely an example, and adds no restrictions to the interpretation of the invention. In addition, in the specification and drawings, the same elements as those described in connection with preceding drawings are denoted by like reference numerals, and a detailed description thereof is omitted unless otherwise necessary.

As illustrated in FIG. **1**, an organic EL display device DA adopts an active matrix driving method, and includes an array substrate AR and a counter-substrate CT. The array substrate AR is formed by using a resin layer **10**. The array substrate AR includes switching elements SW**1** to SW**3** and organic EL elements OLED**1** to OLED**3** above an inner surface **10**A of the resin layer **10**.

The resin layer **10** is an insulation layer, which is formed of, for example, a material containing a polyimide (PI) as a main component. The resin layer **10** has a thickness of, e.g. 5 to 30 μm. It is preferable to use, as the material of the resin layer **10**, a material with a high heat resistance such as a polyamide-imide or polyaramide, as well as the polyimide.

The inner surface **10**A of the resin layer **10** is covered with an underlying insulation layer **11** serving as a first insulation film. Specifically, the underlying insulation layer **11** is an undercoating layer, and is formed on the surface of the resin layer **10**. The underlying insulation layer **11** functions as an inner surface barrier film for suppressing entrance of ionic impurities from the resin layer **10** or entrance of moisture via the resin layer **10**. The underlying insulation layer **11** is formed of an inorganic material, and is formed of, for example, a multilayer member of a SiN_X film (silicon nitride film) and a SiO_2 film (silicon oxide film). The underlying insulation layer **11** may be formed by further including a SiON film (silicon oxynitride film). Incidentally, the underlying insulation layer **11** will be described later in detail.

The switching elements SW**1** to SW**3** are formed on the underlying insulation layer **11**. Specifically, the switching elements SW**1** to SW**3** are formed above the surface of the

resin layer via the underlying insulation layer **11**. These switching elements SW**1** to SW**3** are, for example, TFTs (thin-film transistors) each including a semiconductor layer SC as an active layer. The thickness of the semiconductor layer SC is, for example, 50 nm. The switching elements SW**1** to SW**3** have the same structure. In the description below, attention is paid to the switching element SW**1**, and the structure thereof is described more specifically.

The switching element SW**1** is of a top gate type, but this is merely an example and a structure of a bottom gate type is not excluded. However, in the top gate type, since the semiconductor layer, in particular, a part thereof serving as a channel region, is put in direct contact with the underlying insulation layer **11**, the structure of the underlying insulation layer **11** illustrated in the present embodiment is more suitable. In this embodiment, the semiconductor layer SC is formed of p-Si. However, the semiconductor layer SC can be formed of a material other than p-Si, and may be formed of a-Si or an oxide semiconductor formed of an oxide including at least one of indium (In), gallium (Ga) and zinc (Zn). The oxide semiconductor can be formed in a process at lower temperatures than the a-Si or p-Si. In particular, an oxide semiconductor, such as IGZO, is preferable in that the investment cost of manufacturing equipment can be reduced since a manufacturing apparatus, which is used for fabricating TFTs including a-Si semiconductor layers, can also be used as such.

The semiconductor layer SC is formed on the underlying insulation layer **11**, and is covered with a second insulation film **12**. The second insulation film **12** is a gate insulation film and is also disposed on the underlying insulation layer **11**. A gate electrode WG of the switching element SW**1** is formed on the second insulation film **12**. The gate electrode WG is covered with a third insulation film **13**. The third insulation film **13** is also disposed on the second insulation film **12**.

A source electrode WS and a drain electrode WD of the switching element SW**1** are formed on the third insulation film **13**. The source electrode WS and drain electrode WD are put in contact with the semiconductor layer SC. The source electrode WS and drain electrode WD are covered with a fourth insulation film **14**. The fourth insulation film **14** is also disposed on the third insulation film **13**.

The organic EL elements OLED**1** to OLED**3** are formed on the fourth insulation film **14**. In the example illustrated, the organic EL element OLED**1** is electrically connected to the switching element SW**1**, the organic EL element OLED**2** is electrically connected to the switching element SW**2**, and the organic EL element OLED**3** is electrically connected to the switching element SW**3**.

The color of emission light of each of the organic EL elements OLED**1** to OLED**3** is white. In addition, each of the organic EL elements OLED**1** to OLED**3** is configured as a top emission type which emits light toward the counter-substrate CT. The organic EL elements OLED**1** to OLED**3** have the same structure.

The organic EL element OLED**1** includes an anode PE**1** which is formed on the fourth insulation film **14**. The anode PE**1** is in contact with the drain electrode WD of the switching element SW**1** and is electrically connected to the switching element SW**1**. Similarly, the organic EL element OLED**2** includes an anode PE**2** which is electrically connected to the switching element SW**2**, and the organic EL element OLED**3** includes an anode PE**3** which is electrically connected to the switching element SW**3**. The anodes PE**1** to PE**3** may be formed of, for example, a transparent, electrically conducive material such as indium tin oxide (ITO) or indium zinc oxide (IZO), or may be formed of a metallic material such as aluminum (Al), magnesium (Mg), silver (Ag), titanium (Ti), or an alloy thereof, or a multilayer material thereof. In the case of the top emission type, it is desirable that the anodes PE**1** to PE**3** be formed of a metallic material with a high reflectivity.

The organic EL elements OLED**1** to OLED**3** further include an organic light emission layer ORG and a cathode CE. The organic light emission layer ORG is located on the anodes PE**1** to PE**3**. The organic light emission layer ORG is continuously formed, without a break, over the organic EL elements OLED**1** to OLED**3**. The cathode CE is located on the organic light emission layer ORG. In addition, the cathode CE is continuously formed, without a break, over the organic EL elements OLED**1** to OLED**3**. The cathode CE is formed of, for example, a transparent, electrically conductive material such as ITO or IZO.

Specifically, the organic EL element OLED**1** is composed of the anode PE**1**, organic light emission layer ORG and cathode CE. Similarly, the organic EL element OLED**2** is composed of the anode PE**2**, organic light emission layer ORG and cathode CE, and the organic EL element OLED**3** is composed of the anode PE**3**, organic light emission layer ORG and cathode CE.

In the organic EL elements OLED**1** to OLED**3**, a hole-injection layer or a hole-transport layer may be further provided between each of the anodes PE**1** to PE**3** and the organic light emission layer ORG, and an electron-injection layer or an electron-transport layer may be further provided between the organic light emission layer ORG and the cathode CE.

The organic EL elements OLED**1** to OLED**3** are partitioned by ribs **15**. The ribs **15** are formed on the fourth insulation film **14** and cover the edges of the anodes PE**1** to PE**3**. Although not described in detail, the ribs **15** are formed, for example, in a grid shape or in a stripe shape on the fourth insulation film **14**. The ribs **15** are covered with the organic light emission layer ORG. Specifically, the organic light emission layer ORG extends over not only the anodes PE**1** to PE**3** but also over the ribs **15**.

The counter-substrate CT is formed by using a transparent resin layer **30**. The counter-substrate CT includes a first color filter **31**, a second color filter **32** and a third color filter **33** above an inner surface **30**A of the resin layer **30**.

The resin layer **30** is a transparent insulative substrate, which is formed of, for example, a material containing a polyimide (PI) as a main component. The resin layer **30** has a thickness of, e.g. 5 to 30 μm. As the material of the resin layer **30**, the same material as the resin layer **10** is applicable. In particular, since light emitted from the top-emission type organic EL elements OLED**1** to OLED**3** passes through the resin layer **30**, it is desirable that the resin layer **30** be formed of a material with high transparency.

The first color filter **31** is opposed to the organic EL element OLED**1** and passes a light component of a blue wavelength of white light. The second color filter **32** is opposed to the organic EL element OLED**2** and passes a light component of a green wavelength of white light. The third color filter **33** is opposed to the organic EL element OLED**3** and passes a light component of a red wavelength of white light. A boundary between the first color filter **31** and second color filter **32**, a boundary between the second color filter **32** and third color filter **33** and a boundary between the first color filter **31** and third color filter **33** are located above the ribs **15**.

The array substrate AR and counter-substrate CT are attached by a transparent adhesive **40**. Specifically, the

adhesive **40** is interposed between the organic EL element OLED**1** and first color filter **31**, between the organic EL element OLED**2** and second color filter **32** and between the organic EL element OLED**3** and third color filter **33**. In the meantime, a barrier film (sealing film), which protects the organic EL elements OLED**1** to OLED**3** from contaminants such as moisture, oxygen and hydrogen, may be disposed between the cathode and the adhesive **40**.

According to the organic EL display device DA, when each of the organic EL elements OLED**1** to OLED**3** has emitted light, this radiated light (white light) is emitted to the outside through the first color filter **31**, second color filter **32** or third color filter **33**. At this time, a light component of a blue wavelength of the white light, which has been radiated from the organic EL element OLED**1**, passes through the first color filter **31**. In addition, a light component of a green wavelength of the white light, which has been radiated from the organic EL element OLED**2**, passes through the second color filter **32**. A light component of a red wavelength of the white light, which has been radiated from the organic EL element OLED**3**, passes through the third color filter **33**. Thereby, color display is realized.

Next, the underlying insulation layer **11** is described in detail.

As illustrated in FIG. **2**, the underlying insulation layer **11** is formed on the surface of the resin layer **10**. The underlying insulation layer **11** includes a three-layer multilayer structure of a first silicon oxide film **1**, a silicon nitride film **2** and a second silicon oxide film **3**. In this embodiment, the underlying insulation layer **11** is formed of these three layers alone.

The first silicon oxide film **1** is formed on the surface of the resin layer **10** by using SiO_2. Thus, in the underlying insulation layer **11**, the layer that is in contact with the resin layer **10** is the first silicon oxide film **1**. The thickness of the first silicon oxide film **1** is, for example, 50 nm.

The silicon nitride film **2** is formed above the first silicon oxide film **1** by using SiN_g. In this embodiment, the silicon nitride film **2** is formed on the first silicon oxide film **1**. The thickness of the silicon nitride film **2** is, for example, 50 nm.

The second silicon oxide film **3** is formed above the silicon nitride film **2** by using SiO_2. In this embodiment, the second silicon oxide film **3** is formed on the silicon nitride film **2**. Thus, in the underlying insulation layer **11**, the layer that is in contact with the semiconductor layer SC, which functions as the active layer of the switching element (TFT), is the second silicon oxide film **3**. The thickness of the second silicon oxide film **3** is, for example, 300 nm.

Next, a description is given of an example of a method of manufacturing the organic EL display device DA of the present embodiment.

As illustrated in FIG. **2**, to start with, a glass substrate **100** is prepared as a support substrate. Subsequently, the glass substrate **100** is washed (brush washing). Then, a polyimide precursor compound, which is a varnish-like composition, is coated with a thickness of 5 to 30 μm on the glass substrate **100** (slit coating) by using a film-forming device such as a slit coater. Thereafter, the polyimide precursor compound is cured by heat treatment at 480° C. for one hour. Thus, a resin layer **10** is formed.

Following the above, the glass substrate **100**, on which the resin layer **10** is formed, is placed in a reaction chamber of a parallel-plate-type plasma CVD apparatus. Then, in a state in which the temperature of the glass substrate **100** is about 400° C., four layers, namely a first silicon oxide film **1** with a thickness of 50 nm, a silicon nitride film **2** with a thickness of 50 nm, a second silicon oxide film **3** with a thickness of 300 nm and an a-Si layer **5** with a thickness of 50 nm, are successively formed in order on the glass substrate **100**, while supply gases into the reaction chamber are being switched.

The first silicon oxide film **1** is formed on the resin layer **10** by plasma decomposition of a mixture gas of SiH_4 gas and N_2O gas. The silicon nitride film **2** is formed on the first silicon oxide film **1** by plasma decomposition of a mixture gas of SiH_4 gas and NH_3 gas. The second silicon oxide film **3** is formed on the silicon nitride film **2** by plasma decomposition of a mixture gas of SiH_4 gas and N_2O gas. The a-Si layer **5** is formed on the second silicon oxide film **3** by plasma decomposition of SiH_4 gas.

From the above, the above-described four layers can be successively formed by continuing to flow SiH_4 gas, and switching the sub-gases. Thus, with the tact time being hardly increased, the underlying insulation layer **11** (underlying insulation layer **11** and a-Si layer **5**) can be formed.

Thereafter, the a-Si layer **5** is patterned, the patterned a-Si is irradiated with a laser beam, etc., and the a-Si is polycrystallized. Incidentally, it is advantageous that the amount of hydrogen in the a-Si layer **5** is small, since no bumping or the like will occur. Normally, in a heating step after the film formation, hydrogen is discharged to the outside of the a-Si layer **5**. If the tact time is taken into account, it is better that the initial amount of hydrogen is small. Thus, it is desirable that the a-Si layer **5** be formed at as high as possible temperatures.

As illustrated in FIG. **1** and FIG. **2**, subsequently, by using p-Si formed on the underlying insulation layer **11**, switching elements SW**1** to SW**3** are formed on the underlying insulation layer **11** through an ordinary TFT fabrication process using low-temperature p-Si. In addition, on the underlying insulation layer **11**, not only the switching elements, but also a second insulation film **12**, a third insulation film **13** and a fourth insulation film **14** are formed, and at the same time various wirings are formed.

Then, on the fourth insulation film **14**, organic EL elements OLED**1** to OLED**3** are formed. Specifically, after anodes PE**1** to PE**3** are formed on the fourth insulation film **14**, ribs **15** are formed, and an organic light emission layer ORG and a cathode CE are formed. Where necessary, a sealing film is formed on the organic EL elements OLED**1** to OLED**3**.

On the other hand, although not illustrated, a glass substrate, which is different from the above-described glass substrate **100**, is prepared as a support substrate. Subsequently, the glass substrate is washed. Then, a polyimide precursor compound, which is a varnish-like composition, is coated with a thickness of 5 to 30 μm on the glass substrate by using a film-forming device such as a slit coater. Thereafter, the polyimide precursor compound is cured by heat treatment, and a resin layer **30** is formed.

Subsequently, a first color filter **31**, a second color filter **32** and a third color filter **33** are formed on the resin layer **30**. Thereafter, an adhesive **40** is coated on the surfaces of the first to third color filters **31** to **33**.

Next, the glass substrate **100** and the glass substrate, on which the first to third color filters **31** to **33** are formed, are attached. Specifically, the surface of the array substrate AR on that side, on which the organic EL elements OLED**1** to OLED**3** are located, and the surface of the counter-substrate CT on that side, on which the first to third color filters **31** to **33** are located, are bonded by the adhesive **40**.

Thereafter, the glass substrate **100** is peeled from the resin layer **10**, and the other glass substrate is peeled from the resin layer **30**, thus removing the two glass substrates.

Thereby, the organic EL display device DA of the present embodiment is manufactured.

According to the organic EL display device DA of the first embodiment with the above-described structure, the organic EL display device DA comprises the underlying insulation layer **11** formed on the surface of the resin layer **10**, and the switching elements SW**1** to SW**3** formed above the surface of the resin layer **10** via the underlying insulation layer **11**.

The underlying insulation layer **11** includes the first silicon oxide film **1**. In the underlying insulation layer **11**, the first silicon oxide film **1** is in contact with the resin layer **10**. When the first silicon oxide film **1** is formed, since the mixture gas including N_2O gas is supplied into the reaction chamber, the surface of the resin layer **10**, which is heated at a high temperature of about 400° C., is hardly exposed to a reducing atmosphere. Thereby, a change in quality of the resin layer **10** (in particular, the surface of the resin layer **10**) can be reduced, and the flexibility of the resin layer **10** can be maintained.

The underlying insulation layer **11** includes the silicon nitride film **2** formed above the first silicon oxide film **1**. When the silicon nitride film **2** is formed, since the resin layer **10** is covered with the first silicon oxide film **1**, the flexibility of the resin layer **10** can be maintained. Since the silicon nitride film **2** has an excellent ion-blocking property, contamination of the switching elements SW**1** to SW**3** (the semiconductor layers SC) can be prevented.

The underlying insulation layer **11** includes the second silicon oxide film **3** formed above the silicon nitride film **2**. In the underlying insulation layer **11**, the second silicon oxide film **3** is in contact with the active layers (semiconductor layers SC) of the switching elements SW**1** to SW**3**. The semiconductor layer SC is provided, not immediately above the silicon nitride film **2**, but above the silicon nitride film **2** via the second silicon oxide film **3**. The second silicon oxide film **3** can prevent supply of nitrogen atoms (excess nitrogen) from the silicon nitride film **2** into the semiconductor layer SC. Thereby, it becomes possible to prevent an adverse effect on the electrical characteristics of the switching elements SW**1** to SW**3** (semiconductor layers SC).

From the above, the organic EL display device DA with excellent flexibility and product reliability can be obtained.

Next, a display device of a second embodiment is described. In this embodiment, the same functional parts as in the above-described first embodiment are denoted by like reference numerals, and a detailed description thereof is omitted.

As illustrated in FIG. **3** and FIG. **2**, in this embodiment, organic EL display devices DA of Examples 1 to 4 are described.

Example 1

The organic EL display device DA of Example 1 is formed like the organic EL display device DA of the first embodiment. Incidentally, the thickness of the first silicon oxide film **1** is 50 nm.

Example 2

The organic EL display device DA of Example 2 is formed like the organic EL display device DA of the first embodiment, except for the thickness of the first silicon oxide film **1**. Incidentally, the thickness of the first silicon oxide film **1** is 10 nm.

Example 3

The organic EL display device DA of Example 3 is formed like the organic EL display device DA of the first embodiment, except for the thickness of the first silicon oxide film **1**. Incidentally, the thickness of the first silicon oxide film **1** is 30 nm.

Example 4

The organic EL display device DA of Example 4 is formed like the organic EL display device DA of the first embodiment, except for the thickness of the first silicon oxide film **1**. Incidentally, the thickness of the first silicon oxide film **1** is 100 nm.

Next, the flexibility of each of the organic EL display devices DA of Examples 1 to 4 is evaluated. In this embodiment, the evaluation of the flexibility was conducted at a stage at which the organic EL display device DA was fabricated halfway up to a fabrication step (i.e. formation of a-Si layer **5**). The reason for this is that the evaluation of the flexibility is sufficient if the manufacturing process progresses to this stage. In addition, for the purpose of comparison with the flexibility of each of the organic EL display devices DA of Examples 1 to 4, the flexibility of each of organic EL display devices of Comparative Examples 1 to 3 was also evaluated.

In Examples 1 to 4, at a time point when the multilayer member of the resin layer **10**, underlying insulation layer **11** and a-Si layer **5** was formed on the glass substrate **100**, the glass substrate **100** was peeled from the resin layer **10**, and the flexibility of the taken-out multilayer member was evaluated.

In Comparative Example 1, at a time point when the resin layer **10** of the above-described first embodiment was formed on the glass substrate **100**, the glass substrate **100** was peeled from the resin layer **10**, and the flexibility of the taken-out resin layer **10** alone was evaluated.

In Comparative Example 2, at a time point when the multilayer member of the resin layer **10** and second silicon oxide film **3** of the above-described first embodiment was formed on the glass substrate **100**, the glass substrate **100** was peeled from the resin layer **10**, and the flexibility of the taken-out multilayer member was evaluated. Incidentally, the multilayer member of Comparative Example 2 is formed without the first silicon oxide film **1** and silicon nitride film **2**.

In Comparative Example 3, at a time point when the multilayer member of the resin layer **10**, silicon nitride film **2**, second silicon oxide film **3** and a-Si layer **5** of the above-described first embodiment was formed on the glass substrate **100**, the glass substrate **100** was peeled from the resin layer **10**, and the flexibility of the taken-out multilayer member was evaluated. Incidentally, the multilayer member of Comparative Example 3 is formed without the first silicon oxide film **1**.

Next, a description is given of a jig which is used for the evaluation of an evaluation object such as the above-described multilayer member.

As illustrated in FIG. **4**, a jig **200** includes a pair of rods **201**, **202**. The rods **201** and **202** are provided in parallel with a predetermined interval. The cross-sectional shape of the rod **201**, **202** is a circle (perfect circle). The interval between the rods **201** and **202** is adjustable, and may be adjusted such that the evaluation object is fixed, or such that the evaluation object can be passed between the rods **201** and **202**. In addition, as the rods **201** and **202**, a plurality of kinds of rods with different diameters may be changed and used. In the present case, the diameter of the rod **201**, **202** is 2R.

When the flexibility of the evaluation object is evaluated by using the jig **200** illustrated in FIG. **4**, the evaluation

object is inserted between the rods **201** and **202**, and the evaluation object is clamped and fixed between the rods **201** and **202**. Then, the evaluation object is bent by 180°, and a minimum bend radius of the evaluation object at a time when no plastic deformation occurred in the evaluation object is defined as a minimum bend R. Based on the value of the minimum bend R, the flexibility of the evaluation object is evaluated.

In addition, when the minimum bend R is evaluated (measured), the evaluation is performed by applying an initial stress F in an upward direction or a downward direction in the Figure. When a downward minimum bend R is evaluated, the evaluation object can be bent downward by 180° by putting the evaluation object in close contact with half the periphery of the rod **201** by, for example, applying a downward initial stress F. Similarly, when an upward minimum bend R is evaluated, the evaluation object can be bent upward by 180° by putting the evaluation object in close contact with half the periphery of the rod **202** by, for example, applying an upward initial stress F. At this time, by gradually decreasing the diameter of the rod **201**, **202** and evaluating (inspecting) the presence/absence of plastic deformation in the evaluation object, the minimum bend R can be found.

As shown in FIG. **3**, the minimum bend R of the multilayer member of each of Examples 1 to 4 was at least 2 mm in each of the downward direction and upward direction. Thereby, it was understood that the multilayer member of each of Examples 1 to 4 was excellent in flexibility.

In addition, the minimum bend R of each of the resin layer **10** of Comparative Example 1 and the multilayer member of Comparative Example 2 was at least 2 mm in each of the downward direction and upward direction. From this, it was understood that each of the resin layer **10** of Comparative Example 1 and the multilayer member of Comparative Example 2 was excellent in flexibility.

However, in the multilayer member of Comparative Example 3, the downward minimum bend R was 25 mm and the upward minimum bend R was 30 mm. From this, it is understood that the flexibility of the multilayer member of Comparative Example 3 is lost. In addition, from the fact that the upward minimum bend R is greater than the downward minimum bend R, it is understood that the resin layer **10** (in particular, the surface of the resin layer **10**) changed in quality and the flexibility of the resin layer **10** was lost.

According to the organic EL display device DA of the second embodiment with the above-described structure, the organic EL display device DA comprises the underlying insulation layer **11** formed on the surface of the resin layer **10**, and the switching elements SW**1** to SW**3**. The underlying insulation layer **11** includes the first silicon oxide film **1**, silicon nitride film **2** and second silicon oxide film **3**.

Not only in the case where the thickness of the first silicon oxide layer **1** is 50 nm, but also in the case where the thickness is any one of 10 nm, 30 nm and 100 nm, the flexibility of the resin layer **10** can be maintained. Thus, in order to maintain the flexibility of the resin layer **10** (organic EL display device DA), it is preferable that the thickness of the first silicon oxide film **1** is 10 nm or more, and 100 nm or less.

Incidentally, in order to maintain the flexibility of the resin layer **10** (organic EL display device DA), the thickness of the first silicon oxide film **1** may exceed 100 nm. However, as the first silicon oxide film **1** becomes thicker, this leads to an increase in time of film formation and loss of uniformity in thickness.

Besides, in the second embodiment, the same advantageous effects as in the first embodiment can be obtained.

From the above, the organic EL display device DA with excellent flexibility and product reliability can be obtained.

Next, a display device of a third embodiment is described. In this embodiment, the same functional parts as in the above-described first embodiment are denoted by like reference numerals, and a detailed description thereof is omitted.

As illustrated in FIG. **5**, the organic EL display device DA is formed like the above-described first embodiment. When the organic EL display device DA is manufactured, a first silicon oxide film **1** is formed so as to completely cover the resin layer **10**. Incidentally, although not illustrated, not only the first silicon oxide film **1**, but all of the first silicon oxide film **1**, silicon nitride film **2** and second silicon oxide film **3** are formed so as to completely cover the resin layer **10**. A peripheral edge portion of the first silicon oxide film **1** is located on the glass substrate **100** and adhered to the glass substrate **100**. The first silicon oxide film **1** is provided on the glass substrate **100** such that a predetermined distance (e.g. several mm) is provided between the outer peripheral edge of the first silicon oxide film **1** and the outer peripheral edge of the glass substrate **100**.

According to the organic EL display device DA of the third embodiment with the above-described structure, the organic EL display device DA comprises the underlying insulation layer **11** formed on the surface of the resin layer **10**, and the switching elements SW**1** to SW**3**. The underlying insulation layer **11** includes the first silicon oxide film **1**, silicon nitride film **2** and second silicon oxide film **3**. The organic EL display device DA of the third embodiment is formed like the organic EL display device DA of the above-described first embodiment. Thus, in the third embodiment, the same advantageous effects as in the first embodiment can be obtained.

The first silicon oxide film **1** is formed so as to completely cover the resin layer **10**. Thus, a change in quality can be reduced also at the peripheral edge part of the resin layer **10**.

The peripheral edge part of the first silicon oxide film **1** is located on the glass substrate **100**. SiO_2 is excellent in adhesivity to glass. Thus, undesired peeling of the resin layer **10** from the glass substrate **100** can be reduced in the manufacturing process.

The first silicon oxide film **1** is formed such that a predetermined distance is provided between the outer peripheral edge of the first silicon oxide film **1** and the outer peripheral edge of the glass substrate **100**. It is thus possible to reduce the occurrence of peeled matter (waste matter) of the first silicon oxide film **1**, etc., which tends to easily occur when the first silicon oxide film **1**, etc. are formed up to the outer peripheral edge of the glass substrate **100** or the vicinity of the outer peripheral edge.

From the above, the organic EL display device DA with excellent flexibility and product reliability can be obtained.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

For example, the thickness of the second silicon oxide film **3** is not limited to 300 nm, and can be variously changed. In order to avoid an adverse effect on the electrical characteristics of the switching elements SW**1** to SW**3** (semiconductor layers SC), it is preferable that the thickness of the second silicon oxide film **3** is 100 nm or more, and 500 nm or less. In addition, the second silicon oxide film **3** is irradiated with a laser beam, or is heated. From the above, too, it is preferable that the thickness of the second silicon oxide film **3** is 100 nm or more.

In the meantime, the thickness of the second silicon oxide film **3** may be less than 100 nm. However, as the second silicon oxide film **3** becomes thinner, an adverse effect tends to be easily occur on the electrical characteristics of the switching elements SW**1** to SW**3** (semiconductor layers SC).

In addition, the thickness of the second silicon oxide film **3** may exceed 500 nm. However, as the second silicon oxide film **3** becomes thicker, this leads to an increase in time of film formation and loss of uniformity in thickness.

If the underlying insulation layer **11** includes the three-layer multilayer structure of the first silicon oxide film **1** which is in contact with the resin layer **10**, the silicon nitride film **2** formed above the first silicon oxide film **1**, and the second silicon oxide film **3** which is formed above the silicon nitride film **2** and is in contact with the active layers (semiconductor layers SC) of the switching elements SW**1** to SW**3**, the above-described advantageous effects can be obtained. Thus, in the underlying insulation layer **11**, the above-described three layers may not be successively stacked and formed. For example, the underlying insulation layer **11** may be formed of the first silicon oxide film **1**, the silicon nitride film **2** formed on the first silicon oxide film **1**, another proper film (e.g. silicon oxynitride film) formed on the silicon nitride film **2**, and the second silicon oxide film **3** formed on the another proper film.

It should suffice if the underlying insulation layer **11** is formed on a resin layer surface, such as the surface of the resin layer **10**. For example, the organic EL display device DA may further include a glass substrate **100**. In this case, the organic EL display device DA may be formed without peeling the resin layer **10** from the glass substrate **100**. Besides, the organic EL display device DA may include a plastic substrate (resin substrate) in place of the resin layer **10**. In this case, it should suffice if the underlying insulation layer **11** is formed on the surface of the plastic substrate.

The semiconductor layer SC may be formed of a semiconductor material other than p-Si. For example, the semiconductor layer SC may be formed of a-Si.

The colors of emission lights of the organic EL elements OLED**1** to OLED**3** are not limited to white, and may be, for instance, red, green and blue. In this case, the organic EL display device DA can emit (display) red light, green light and blue light, without the first color filter **31**, second color filter **32** and third color filter **33**.

The embodiments of the present invention are not limited to the application to the above-described organic EL display device DA. The embodiments are also applicable to other organic EL display devices (e.g. a bottom-emission-type organic EL display device, and an organic EL device in which light emission layers of RGB are formed by selective coating), or display devices (e.g. a display device using a liquid crystal element, or an electrophoresis element) other than organic EL display devices. For example, the self-luminous element is not limited to a diode (organic EL diode), and use may be made of various display elements which are configured to be self-luminous. Needless to say, the above-described embodiments are applicable to display devices ranging from small/middle-sized display devices to large-sized display devices, without particular restrictions.

What is claimed is:

1. A method of manufacturing a display device comprising:
- forming a resin layer on a glass substrate;
- forming a first silicon oxide film having a thickness of 10 to 50 nm above the resin layer such that a peripheral portion of the first silicon oxide film contacts with the glass substrate;
- forming a silicon nitride film above the first silicon oxide film;
- forming a second silicon oxide film above the silicon nitride film;
- forming an active layer of a thin-film transistor above the second silicon oxide film; and
- peeling the resin layer from the glass substrate,
- wherein
- the resin layer, above which the active layer is formed, has a downward minimum bend radius R of 2 mm or less, wherein the downward minimum bend radius R is obtained by bending an evaluation object downward by 180° by putting the evaluation object in close contact with half a periphery of a rod.

2. The method of claim **1**, wherein the first silicon oxide film is in contact with the resin layer.

3. The method of claim **2**, wherein the second silicon oxide film is in contact with the active layer of the thin-film transistor.

4. The method of claim **3**, wherein the active layer of the thin-film transistor is formed of polysilicon.

5. The method of claim **3**, wherein the resin layer has a thickness of 5-30 μm.

6. The method of claim **3**, wherein the second silicon oxide film has a thickness of 100-500 nm.

7. The method of claim **2**, wherein the active layer of the thin-film transistor is formed of polysilicon.

8. The method of claim **2**, wherein the resin layer has a thickness of 5-30 μm.

9. The method of claim **2**, wherein the second silicon oxide film has a thickness of 100-500 nm.

10. The method of claim **1**, wherein the second silicon oxide film is in contact with the active layer of the thin-film transistor.

11. The method of claim **1**, wherein the active layer of the thin-film transistor is formed of polysilicon.

12. The method of claim **1**, wherein the resin layer has a thickness of 5-30 μm.

13. The method of claim **1**, wherein the second silicon oxide film has a thickness of 100-500 nm.

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